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Troглоconcha, A New Genus of Larocheine Scissurellidae
(Gastropoda: Vetigastropoda) from Tropical Indo-Pacific Submarine Caves

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Abstract. A new genus *Troглоconcha* is proposed for *Troглоconcha ohashii*, sp. nov. within the Larocheinae Marshall, 1993, a unique subfamily that lacks an anal slit or foramen among the Scissurellidae (Vetigastropoda). The new species inhabits gloomy to totally dark, shallow-water submarine caves and deep caverns and is distributed widely in the tropical to subtropical eastern Indian and western Pacific oceans. *T. ohashii*, sp. nov. has papillate cephalic tentacles unlike species of *Larochea* (the condition is unknown for *Larocheopsis*), has a small operculum, and does not show sexual dimorphism in shell features unlike species of *Larochea* and *Larocheopsis*. One modern species *Troглоconcha tessellata*, sp. nov. from Okinawa, Japan, and one late Oligocene species *Larocheopsis marshalli* Lozouet, 1998, from France, both represented by shell alone, are assigned to the new genus.

INTRODUCTION

Mollusks from submarine caves primarily accessible through SCUBA diving have been investigated in recent years. Submarine cave mollusks have been most extensively sampled in the Indo-Pacific Oceans (Kase & Hayami, 1992; Hayami & Kase, 1992, 1993, 1996; Kase, 1998a, b, c, 1999; Kase & Kano, 1999; Kano & Kase, 2000) and in the Mediterranean Sea (Di Geronimo et al., 1993, 1997; La Perna, 1998). The investigation of cave mollusks has produced interesting questions, both taxonomically and biogeographically. New mollusks of little known and unknown taxa, and many living features of interesting species previously known only as empty shells have been discovered (Kase & Hayami, 1992; Kase, 1998a, b, c, 1999; Kase & Kano, 1999; Kano & Kase, 2000).

In this paper, a new genus and two new species of the scissurellid subfamily Larocheinae are described. A total of over 1500 specimens of the new species *Troглоconcha ohashii*, mostly represented by empty shells, were collected from a number of submarine caves, caverns, and crevices in the tropical western Pacific and eastern Indian oceans. The habitats are from 4 m to 51 m in depth, gloomy to totally dark inside, mostly filled with calcare-

ous muddy sand, and may have been formed mostly during the low sea levels during the late Quaternary. *Troглоconcha tessellata*, on the other hand, is known only from empty shells at a single locality.

MATERIALS AND METHODS

Shell-bearing bottom sediments were collected by hand and/or hand-made sampler and sieved with 0.5 mm mesh. The shells were picked under a binocular microscope. In spite of an abundant occurrence of empty shells, live specimens are rare and are represented only by 13 specimens of *T. ohashii*. They have been found only in submarine caves, and have not been found in nearby shallow-water bottoms outside of the caves, nor have they been recorded from deep waters. It seems, however, that the species is not restricted to cave habitats, but is living in coral rubble deeply embedded in inaccessible sublittoral situations. Live animals were collected by brushing the under-surface of coral rubble on the bottom sediments. In "Cross Hole" of Irabu islet of the Miyako Islands, live specimens were collected, together with a number of live bivalves and gastropods that are associated with patchy colonies of a tube-forming annelid. The bivalves are *Cosa waikikia* (Dall, Bartsch & Rehder, 1938), *Chlamydella incubata* Hayami & Kase, 1993, *Chlamydella tenuissima* Hayami & Kase, 1993, etc., which attach to the annelid tubes with byssus. The associated gastropods are scissurellids such as *Scissurella stauinea* A. Adams, 1862, and

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undetermined species of *Scissurella*, *Sinezona*, and risoids.

Live animals were relaxed in 7.5% magnesium chloride, fixed in 10% formalin for 24 hours, and preserved in 75% ethanol. For SEM observation of soft parts, animals were gradually dehydrated, transferred to t-butyl alcohol, and dried with a freeze-drier JEOL JFD-300. Radulae were removed from the buccal mass, soaked in sodium hypochlorite for several minutes, then washed, mounted, and dried.

SYSTEMATICS

Superorder VETIGASTROPODA Salvini-Plawen, 1980

Family SCISSURELLIDAE Gray, 1847

Subfamily LAROCHEINAE Finlay, 1927

Genus *Troглоconcha* Kase & Kano, gen. nov.

Type species: *Troглоconcha ohashii* Kase & Kano, sp. nov.

Diagnosis: Shell minute, thin, fragile, umbilicate, laterally expanded turbiniform, without anal slit or foramen; aperture large, inner lip simple, without internal inner septum; protoconch almost smooth; teleoconch whorls rounded, with reticulate sculpture. Radula rhipidoglossate with formula $\infty + 5 + 1 + 5 + \infty$; central tooth broadest, lateral 1 broad, laterals 2–4 with slender shafts bowed outwardly near base, lateral 5 with quadrangular broad base, tapered to tip. Operculum rudimentary, with diameter of $\frac{1}{4}$ of shell aperture. Animal with papillate cephalic and non-papillate epipodial tentacles, without brood pouch. Gonochoristic, no size differences between sexes.

Etymology: The genus name is from the combination of Latin, *Troglo* (cave) and *concha* (shell), referring to the habitat of the type species.

Discussion: Finlay (1927) established the family Larocheidae to accommodate the single species *Larochea miranda* Finlay, 1927, from off northern New Zealand, and tentatively placed the family close to the caenogastropod family Merriidae (= Vanikoridae). Marshall (1993) examined the shells and radulae of *Larochea* and his new genus *Larocheopsis*, and correctly placed the taxon as a subfamily of the Scissurellidae. He defined the subfamily as having these characters: (1) a minute, thin, haliotiform-turbiniform teleoconch with fine reticulate (*Larochea*) or almost smooth (*Larocheopsis*) sculpture, without anal slit or foramen; (2) a smooth (*Larocheopsis*) or finely granulate (*Larochea*) protoconch; (3) a radula with the formula $\infty + 5 + 1 + 5 + \infty$; (4) animal with right ctenidium absent, left ctenidium monopectinate (*Larochea*); and (5) cephalic and epipodial tentacles non-papillate (*Larochea*).

The new genus *Troглоconcha* is erected for *T. ohashii*, sp. nov. as the type species. One modern species *T. tes-*

Table 1

Gonad analysis of *Troглоconcha ohashii* sp. nov. Shell size is measured maximum shell diameter when shell aperture is placed on flat surface.

Shell size (mm)	Gonad	Locality
1.30	testis	Miyako island, Japan
1.20	ovary	Miyako island, Japan
1.00+	ovary	Miyako island, Japan
1.00	ovary	Miyako island, Japan
0.75	ovary	Saipan

selata, sp. nov. from Okinawa, Japan, and one Oligocene species *Troглоconcha marshalli* (new combination, = *Larocheopsis marshalli* Lozouet, 1998) from France, both represented by shell alone, are allocated to the new genus on the basis of the overall shell similarity to *T. ohashii*. The shell, radular, and ctenidial characters indicate that the new genus is a member of the Larocheinae (Figures 1–3). However, there are some differences that warrant separating *T. ohashii* from the other larocheinine species at the generic level. The new genus has a smooth protoconch like *Larocheopsis* (Figure 2), but differs from the latter in having reticulate teleoconch ornamentation (Figure 1). In radular morphology, *T. ohashii* has a fifth lateral tooth which is more slender than that of *Larochea*, and has a first lateral tooth more slender than that of *Larocheopsis* (Figure 3D). Moreover, *T. ohashii* has a rudimentary operculum and micropapillae on cephalic tentacles (Figure 3A–C), whereas the operculum is absent in *Larochea* and *Larocheopsis*, and the tentacles are not papillate in *Larochea* (the condition is unknown for *Larocheopsis*) (B. Marshall, 1993, personal communication).

Reproductive traits further distinguish the new genus. In *Larochea*, young are brooded in the right subpallial cavity, and the shells exhibit sexual dimorphism: the female has a large internal inner lip septum, whereas there is a small internal inner lip septum in the male. In *Larocheopsis*, an internal inner lip septum is absent, and the male seems to be smaller than the female and firmly attaches to the body whorl outside of the parietal area (Marshall, 1993). *T. ohashii*, on the other hand, has neither the internal inner lip septum nor the brooded young in the subpallial cavity, and it lacks the dwarf males on the body whorl of the large female shells. A serial thin section analysis of the gonads reveals either testis or ovary in fully grown specimens of *T. ohashii*. Thus, the species is, like *Larochea secunda* Powell, 1937, and *Larochea scitula* Marshall, 1993, evidently gonochoristic and has males and females of similar shell size (Table 1).

Troглоconcha ohashii Kase & Kano, sp. nov.
(Figures 1A–C, 2A, B, 3)

Larochea miranda Finlay, Bandel, 1998:66, pl. 33, figs. 3, 4; non Finlay, 1927.

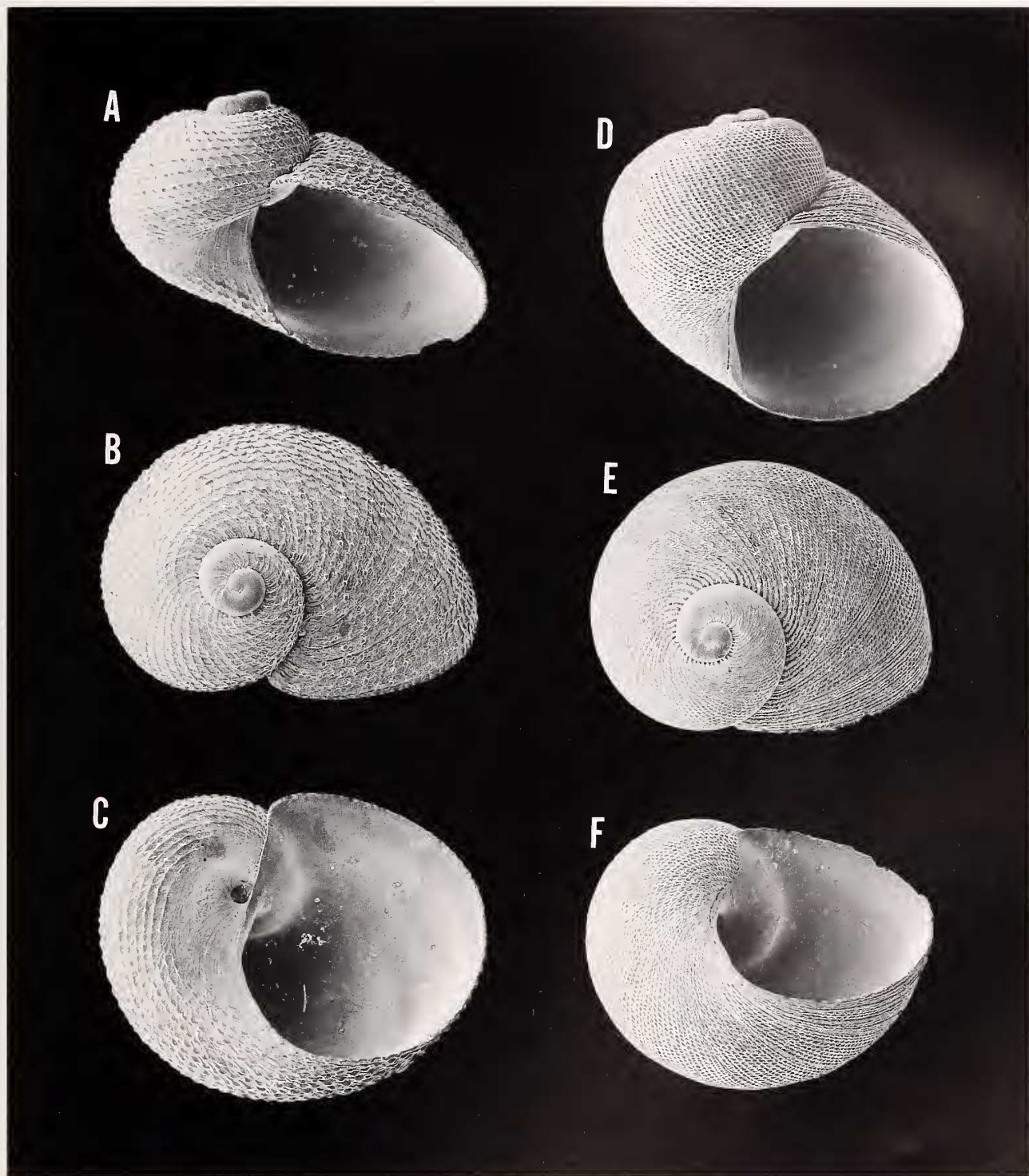


Figure 1. A–C. *Trogloconcha ohashii* Kase & Kano, gen. et sp. nov. Frontal, apical, and basal views of holotype (NSMT Mo72828), 1.13 mm wide, 0.81 mm high, from “Cross Hole,” Irabu islet, Miyako Islands, Okinawa, Japan. D–F. *Trogloconcha tessellata* Kase & Kano, gen. et sp. nov. Frontal, apical, and basal views of holotype (NSMT Mo72830), 1.1 mm wide, 1.02 mm high, from north of Kohama Island, Yaeyama Group, Okinawa.

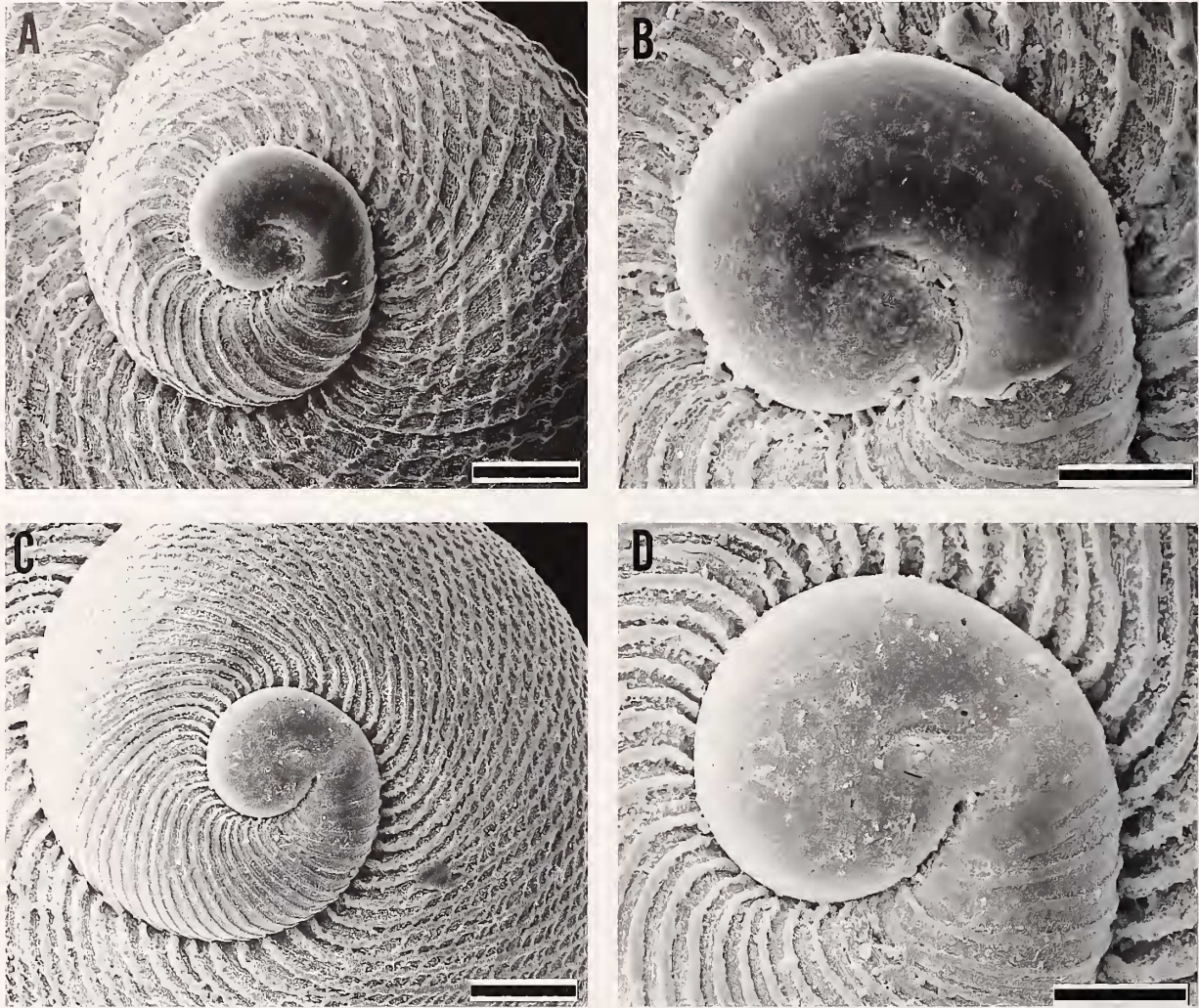


Figure 2. Protoconchs of *Trogloconcha* in apical views. A, B. *Trogloconcha ohashii* Kase & Kano, gen. et sp. nov., holotype, NSMT Mo72828. C, D. *Trogloconcha tessellata* Kase & Kano, gen. et sp. nov., holotype, MSMT Mo72830. Scale bars = 100 μ m for A and C, and 50 μ m for B and D.

Type specimens: Holotype NSMT Mo72828, 0.81 mm high, 1.13 mm wide; paratypes NSMT Mo72829; paratypes MNHM.

Type locality: “Black Hole” diving site, northwest of Shimoji Island, Miyako Group, Okinawa (24°49.1’N, 125°08.3’E); depth 35 m, totally dark inside; calcareous muddy sand.

Distribution: This species is widely distributed in the shallow waters of the tropical and subtropical areas between Cocos Keeling (Indian Ocean) in the west and French Polynesia (western Pacific Ocean) in the east.

Other material examined: COCOS KEELING—1 empty shell from sta. CK1, cavern, west of West Island, 12°10.8’S, 96°48.8’E, depth 48.6 m, gloomy. CHRISTMAS ISLAND (INDIAN OCEAN)—3 empty shells from

sta. XM4, “Thunder Dome” diving site, long cave seemingly connected to land cave(s), north of Christmas Island, depth 9 m, totally dark. BALI, INDONESIA—20 empty shells, Menjangan Island National Park, south side at “Underwater Cave” dive site, shallow crevice, depth 25–30 m. BORNEO, MALAYSIA—116 empty shells from sta. CT, “Turtle Cavern” diving site, long cave, Sipadan island, Sulu Sea, 118°36.5’E, 05°04.8’N, depth 15 m, totally dark. PHILIPPINES—100+ empty shells from sta. AN4, cavern in front of Vistamar Resort, Anilao, Batangas, 13°45.1’N, 120°55.0’E, depth 40 m, gloomy; 38 empty shells from sta. AN3, “Mapatin Cave” diving site, cave, southwest of Maricaban Island, Batangas, 13°40.2’N, 120°49.0’E, depth 46 m, totally dark; 39 empty shells from “Marigondon Cave” diving site, huge cave, south of Mactan Island, 10°15.8’N, 123°59.2’E,

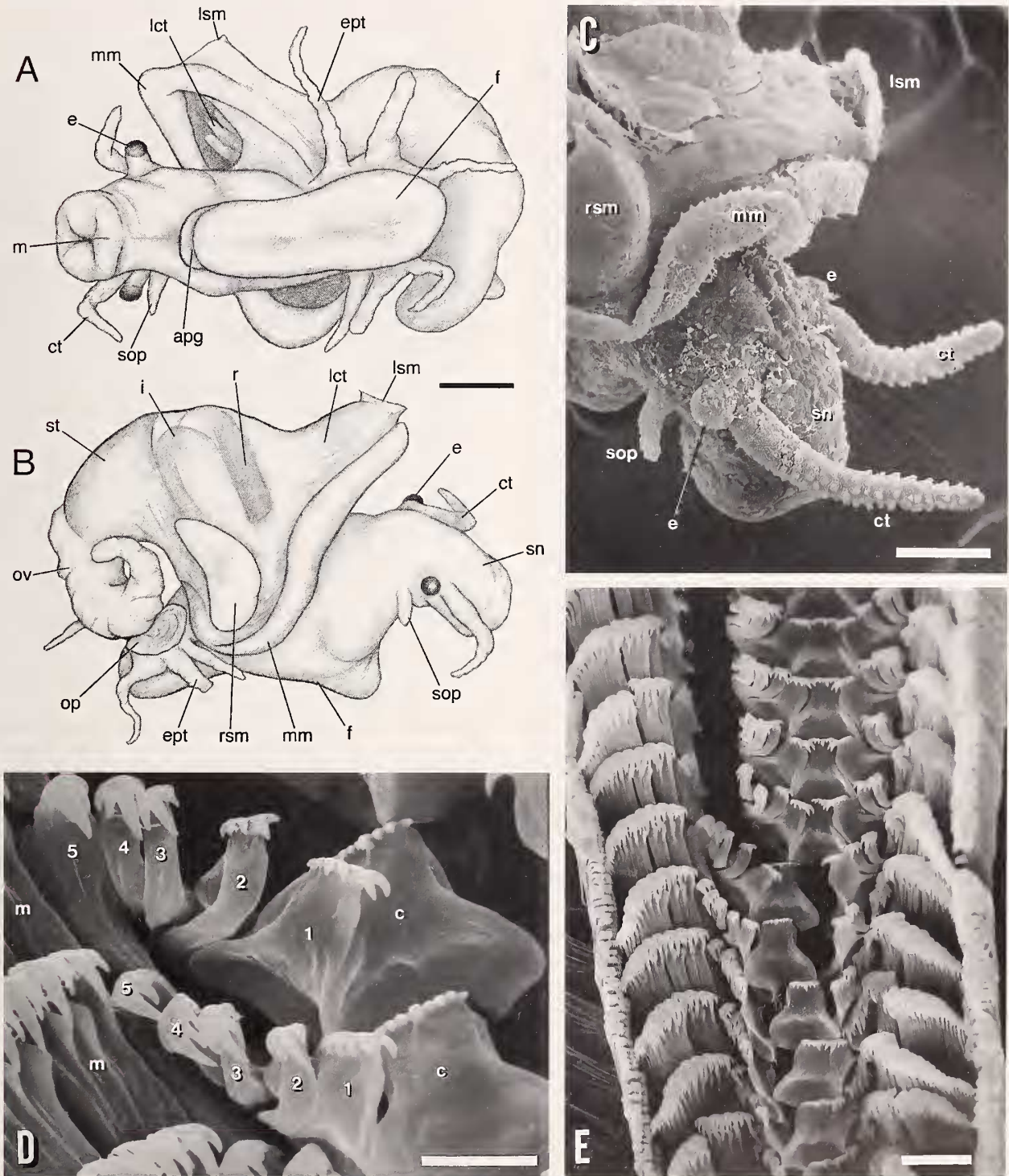


Figure 3. External anatomy and radula of *Trogloconcha ohashii* Kase & Kano, gen. et sp. nov. A, B. Drawings of a female animal from Saipan, removed from shell. Scale bar = 100 μ m. A. Ventral view. B. Dorsal view. Abbreviations: apg, opening of anterior pedal gland; ct, cephalic tentacle; e, closed eye; ept, epipodial tentacle; f, foot; i, intestine; lct, single left ctenidium; lsm, left shell muscle; m, mouth; mm, mantle margin; op, operculum; ov, ovary; r, rectum; rsm, right shell muscle; sn, snout; sop, right subocular peduncle; st, stomach. C. SEM shot of extracted animal from Miyako Islands, Okinawa. Note papillate cephalic tentacles and a subocular peduncle. Scale bar = 100 μ m. D, E. Radula of a specimen from Miyako Islands, Okinawa. D. Enlargement of central (c), lateral (1–5), inner marginal (m) teeth, scale bar = 5 μ m. E. Whole teeth of transverse rows, scale bar = 10 μ m.

depth 27 m, totally dark; 86 empty shells from two caverns, Balicasag Island of Bohol, 09°32.7'N, 123°40.7'E, depth 17 m, gloomy. OKINAWA ISLANDS, OKINAWA, JAPAN—112 empty shells from "Shodokutsu" (= small cave) diving site, cave, east of Ie islet, 26°42.9'N, 127°50.1'E, depth 20 m, totally dark; 4 empty shells from "Daidokutsu" (=large cave) diving site, huge cave, east of Ie islet, 26°42.9'N, 127°50.1'E, depth 20 m, totally dark. MIYAKO ISLANDS, OKINAWA, JAPAN—43 empty and 3 live shells from "Cross Hole" diving site, cave, Irabu islet, 24°51.6'N, 125°09.5'E, depth 15 m, gloomy; 3 empty shells from "Lunch Hole," cave in tidal flat, Irabu Islet, 24°51.6'N, 125°10.0'E, depth 4 m, totally dark; 1 empty shell from "L-arch" diving site, L-shaped cave, Irabu islet, 24°51.7'N, 125°09.7'E, depth 25 m, totally dark; 6 empty shells from "Devil's Palace" diving site, long cave, Shimoji islet, depth approx. 25 m, gloomy; 107 empty shells from "Witch's House" diving site, cave, Shimoji islet, 24°49.3'N, 125°08.3'E, depth 35 m, totally dark; 3 empty shells from "Toriike" diving site, approx. 30 m long tunnel, Irabu islet, 24°49.1'N, 125°08.3'E, depth 12 to 40 m, gloomy. YAEYAMA ISLANDS, OKINAWA, JAPAN—23 empty shells, north of Kohama Island, 24°21.5'N, 123°58.9'E, depth 15 to 20 m, crevices; 2 empty shells from "Sabachi Cave" diving site, Yonaguni Island, totally dark. DAITO ISLANDS (BORODINO ISLANDS), OKINAWA, JAPAN—2 empty shells from "Gon-gon-ana Cave" diving site, cavern, Minami-Daito Island, 25°50.68'N, 131°01.85'E, depth 23 m, gloomy. OGASAWARA ISLANDS (BONIN ISLANDS), JAPAN—1 empty shell from cavern, Otoutojima, gloomy; 2 empty shells from "Giant Cave" diving site, cave, Tatejima, totally dark. TINIAN—200+ empty shells from sta. TN1, huge cave close to "Tinian Grotto" diving site, 15°01.1'N, 145°35.0'E, depth 50 to 51 m, gloomy. SAIPAN—26 empty shells from "Grotto" diving site, cave, Saipan, 15°15.3'N, 145°49.6'E, depth 20 m, totally dark. GUAM—1 empty shell from cavern, Apra Point, 13°27'N, 144°37'E, depth less than 10 m, gloomy. PALAU—100+ empty shells from "Virgin Hole 1," cave branched from main tunnel in reef lagoon, 07°07.2'N, 134°14.1'E, depth 17 m, totally dark; 5 empty shells from "Siaes Tunnel" diving site, huge tunnel, 07°18.7'N, 134°13.6'E, depth 24 to 44 m, gloomy; 55 empty shells from "Blue Hole" diving site, huge cave, 07°08.3'N, 134°13.3'E, depth 36 m to 38 m, totally dark. POHNPEI—1 empty shell from sta. PO1, "Tawag Point" diving site, cavern, 06°53.0'N, 158°06.0'E, depth 26 m; gloomy. NAURU—7 empty shells from sta. NR1, cavern, AW Aiwo, 0°32.5'S, 166°54.5'E, depth 15 to 25.5 m, gloomy. NEW CALEDONIA—3 empty shells from sta. Pins 2, cavern, east of Nuu Powa, Iles des Pins, 22°31.6'S, 169°25.9'E, depth 17 m to 20.9 m, gloomy. VANUATU—6 empty shells from "Taj Mahal" diving site, cave, west of Efate Island, 17°38.4'S, 168°08.7'E, depth 15 m to 18 m, gloomy to totally dark. FIJI—1 empty shell from

a cavern, north of Ono Island, Great Astrolabe Reef, 18°51.8'S, 178°27.0'W, depth 7 m, gloomy inside. TONGA—15 empty shells from sta. VV3-13, "Swallows Cave" diving site, cave, southwest of Falevai Island, Vava'u Group, 18°40.9'S, 174°02.9'W, depth 17 to 18 m, gloomy; 3 empty shells from sta. HA-4, cavern, west of Haano Island, Ha'apai Group, 19°43.1'S, 174°17.4'W, depth 5 m, gloomy. TAHITI—72 empty shells from sta. TH1, TH1-4, "Cave Arue" diving site, cave, west of Tahiti, 17°30.9'S, 149°32.1'W, depth 22 m to 30 m, gloomy.

Description: Shell minute in size, up to 1.34 mm in width, depressed-turbiniform, umbilicate, thin, fragile, opaque white in shell color, with height about $\frac{3}{4}$ of width. Periostracum very thin, colorless. Protoconch smooth, 142 to 176 μm in diameter, tip narrowly rounded, and separated from teleoconch by slightly flared rim. Teleoconch just two volutions in largest specimen, rapidly expanded, evenly rounded and separated by impressed suture; end of mature body whorl descending obliquely and steeply. Sculpture of first half whorl fine, sharp, regularly spaced collabral axial riblets, thereafter finely reticulating collabral riblets and fine spiral cords; intersection of both forming tiny tubercles. Umbilicus wide and deep, rim rounded, and sculptured only by axials inside. Aperture large, subovate, steeply prosocline, and not holostomous. Outer lip thin and sharp, parietal area narrow, and inner lip simply concave, thin, and sharp.

Operculum rudimentary, multispiral, thin, corneous, with diameter of $\frac{1}{4}$ of shell aperture (Figure 3B).

Radula rhipidoglossate, consisting of approx. 85 transverse rows, with formula $\infty + 5 + 1 + 5 + \infty$. Central tooth broadest, enlarging toward base, cutting edge broad and straight, with nine cusps, median cusp largest. Laterals of one to four similarly shaped teeth, tightly interlocked outwardly near base; lateral 1 broader than laterals 2 to 4, cutting area with six cusps, second to innermost cusp longest; lateral 2 with four cusps, also second to innermost cusp longest; laterals 3 and 4 with five cusps, with longest cusp at center; shaft of lateral 5 becomes broader toward base with two angulations projected inwardly at middle and base, cusp six, fourth to innermost cusp longest, two outer teeth minute. Marginal field of more than 40 teeth in each side of row; teeth very slender, cutting edge subtriangular; innermost tooth with six long cusps.

Animal with long cephalic tentacles, closed eyes with short stalks, right subocular peduncle, long epipodial tentacles, right and left shell muscles and left ctenidium. Cephalic tentacles and peduncle bear micropapillae. Epipodial tentacles three on each side, all similar in length. Right shell muscle far larger than left. Left ctenidium monopectinate, with up to 11 leaflets; right ctenidium absent. Rectum terminating as anus near right shell muscle. Sexes separate; no size difference between male and female; brood pouch absent.